DESIGN WIND SPEEDS FOR TROPICAL CYCLONE AREAS OF AUSTRALIA

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Introduction

Analysis of recorded wind speeds has shown, Dorman (1984), that for the greater part of the tropical-cyclone-prone Australian coast, Geraldton through North to Brisbane but excluding Onslow to Port Hedland, the 50-year return period wind gust speed ("V50") is about 40 m/s.

By an independent method, using data of central pressure and coast crossing occurrences, and by making comparisons with the East coast of the United States, this V50 was confirmed. The currently accepted V50 speeds as given in the Australian Wind Code AS1170 Part 2, are generally 55 m/s and design speeds are based on, but are not the same as, this figure.

Wind Speeds From Historical Records

Recorded wind gust speeds taken during the close passing of tropical cyclones were examined for 33 Australian anemometer stations (ibid.). Following the tradition of the Monte Carlo simulationists a certain distance limit was chosen within which a cyclone passing was noted as an "occurrence," and beyond which it was ignored. The initial selection of occurrences was based on a limit of 5 degrees of latitude/longitude.

Criticisms which may be levelled at this approach are:

1. That a particular distance limit is excessive.
2. That not all speeds should be included in the fitting because only those exceeding the general level of the daily maxima (due to non-cyclone winds) should be considered. This level is about 15 m/s. As an extension to this theme, it could be considered that only speeds exceeding 25 m/s, the lower limit of engineering interest, should be considered.

To answer each criticism by satisfaction of the restriction results in fewer speeds being eligible for analysis, and in this way less confidence may be had in the result.

Stations were grouped together in various ways and Table I gives the results of fitting the aggregated speeds from these groups to the Fisher-Tippett Type I distribution. Regardless of which limitations are applied in selecting the speeds to be used in fitting, there is a remarkable stability in the V50 and V2000 values for each group. This gives considerable confidence that the averages are meaningful to an accuracy of a few metres per second.

Wind Speeds by Inference

Other than by analysis of historical measured wind speeds, it is possible to estimate wind speeds for various return periods by using central pressure data and coast crossing occurrences.

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TABLE I

ANALYSIS OF SPEEDS BY COMBINING RECORDS OF GROUPS OF STATIONS

Station Group	Minimum Accepted Speed	Distance Limit	No. of Speed Speed Readings used in Fitting	V50	V2000
	ms^{-1}	degrees		ms^{-1}	ms^{-1}
Group I	0	5.0	902	41	65
(All 33 stations)	0	2.5	488	42	69
	0	1.0	221	42	75
	25	2.5	124	44	76
	25	1.0	78	43	79
Group II	0	5.0	123	61	94
(Port Hedland and	0	2.5	71	65	103
Onslow.)	0	1.0	24	69	117
	25	2.5	32	66	105
	25	1.0	18	66	105
Group III	0	5.0	779	37	58
(All except	0	2.5	417	38	61
Port Hedland and	0	1.0	197	37	64
Onslow)	25	2.5	92	38	64
	25	1.0	60	37	66
Group IV	0	5.0	701	40	62
(Group III less all	0	2.5	388	41	64
south of Geraldton	0	1.0	181	41	68
on West coast and	25	2.5	87	42	68
south of Brisbane	25	1.0	55	41	71
on East coast)					

Lourensz (1981) divides the Northern Australian coast into 100 "sections" each of 100 kilometres length, from Perth in the West to Port Macquarie in the East. The Western Region is from Perth to about Derby, the Northern Region is thence to the Queensland border, and the Eastern Region is all of the Queensland coast, and down to Port Macquarie in New South Wales. Simpson and Riehl (1981) similarly divide the East coast of the United States into 58 "segments" each of 80 kilometres. In the United States "hurricane" strength winds are 33 m/s or higher, and "great hurricane" strength winds are 56 m/s or higher, where speeds are measured as the fastest mile. Using formulae from Simpson and Riehl is found that corresponding gust speeds are 43 and 72 m/s respectively, and corrsponding central pressures are 985 and 935 millibars respectively. From Lourensz, and Simpson and Riehl, the yearly rate of coast crossing of various intensity can be obtained for a particular strike distance - 100 kilometres and 80 kilometres respectively. Taking then an average radius of maximum wind (depending on latitude), the probability of a wind speed of 43 (or 72) m/s may be calculated.

The calculation of probability is:

$$\text{probability} = \left(\frac{\text{no. of crossings}}{\text{no. of years}}\right) \times \left(\frac{\text{diameter of cyclone}}{\text{length of coast}}\right)$$

for the Western region, for example, probability = (23/21)x(50/3300) = 0.0202

The "hurricane" gust speed of 43 m/s is thus calculated to have return periods of 50, 450, and 130 years for the Western, Northern and Eastern Australian Regions respectively, and lower values for the East coast of the United States. At the level of "great hurricane" strength, Simpson and Riehl give a method by which V50 of 67 m/s is found for segments 4 and 5 on the Texas coast. These segments are harder hit than most. Great Hurricanes are very rare in Australia, and only the Port Hedland to Onslow length of coast has suffered sufficient occurrences for meaningful calculations of return period to be made: its vulnerability if found to be similar to that of the East Coast of the United States as a whole.

Comparing both the 985 and 935 millibar levels of coast crossing occurrences, it can be seen that the Onslow to Port Hedland coast has a similar vulnerability to the East coast of the United States as a whole.

Suggested Wind Gust Speeds for Design

Figure 1 is a Fisher-Tippett Type 1 diagram giving gust speeds for various return periods. On this figure are drawn the FT1 lines obtained by fitting the measured tropical cyclone gust speeds to the FT1 distribution. They are plotted for Group II stations and Group IV stations. Also drawn, for comparison, is the FT1 line for non-tropical cyclone wind speeds which was recommended by Dorman (1983). Plotted points are shown for the return periods which were obtained indirectly for the speeds of 43 m/s and 67 m/s. Lines could be drawn through these points with a slope equal to that of either the Group II or Group IV lines, or in between, but to avoid confusion on the figure this has not been done.

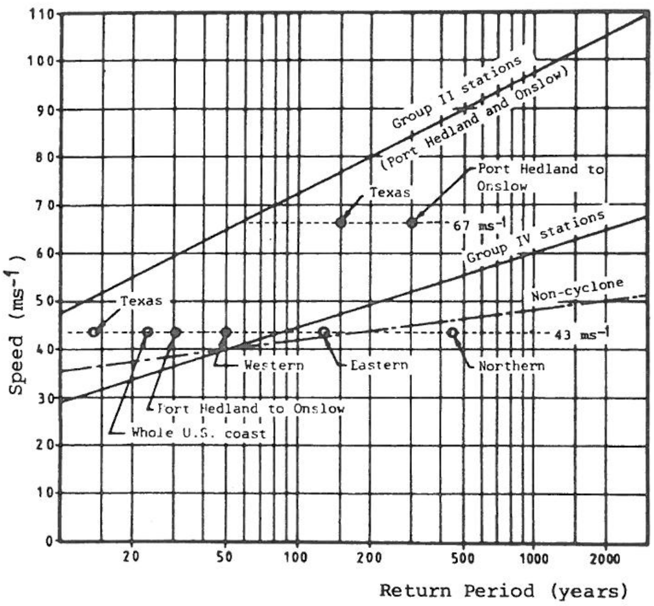

Figure 1

Various estimates of tropical cyclone wind gust speed versus return period. Lines are by fitting of measured speeds, points are by method of inference.

For Group IV stations, considering all the evidence in Figure 1, the average V50 is taken to be 40 m/s. For Group II stations V50 will be taken to be 65 m/s, ignoring the inferred evidence which suggests that V50 is about 50 m/s.

In choosing design speeds for engineering purposes it is not necessary to adhere to the fairly common practice of using the 50-year return period speeds. Firstly, not all wind codes use V50 for design. Some even avoid the concept of return period, merely stating a value of speed which is to be used. The Australian wind code, while using V50 values in general, departs from this for tropical cyclone areas by prescribing design speeds which are 15 percent above the V50 values, the purpose being to make risk of failure equal in cyclone and non-cyclone areas. Secondly, as seen on Figure 1, V50 = 40 m/s for all of non-cyclone-prone Australia. This is the same speed as is now found for the tropical cyclone prone coast, excluding Onslow to Port Hedland. The enormous damage in the event of a strike, and the widespread (with good reason) belief in the community that tropical cyclone winds should be regarded as something exceeding the normal, justify choosing a design speed which is above the normal.

Some respect should be given to United States design speeds when considering what design speeds are appropriate for Australia. Types of building and community values of safety and regard for life are similar in these two countries, and the various United States building codes represent what has been acceptable to that community where a greater number of people have experienced tropical cyclones than in Australia. The ANSI code and the Southern Building Code use 50-year return period speeds for design, each providing the same map of isopleths of speed. Over the whole coast the fastest mile speeds range from 90 to 120 m.p.h. The South Florida Building code and the Bahamas Building Code state, without giving a return period, that 120 m.p.h. is to be used. Using a gust factor of 1.3, from Simpson and Riehl, 90 m.p.h. is equivalent to 52 m/s gust, and 120 m.p.h. is equivalent to 70 m/s gust.

For the coast represented by Group IV stations, the Australian code gives a design speed, for most places, of 63 m/s (55 m/s + 15 %) which now appears to be excessively high when compared to the East coast of the United States, all parts of which are harder hit by cyclones. The V50 speed of 40 m/s, on the other hand, appears to be excessively low. Even 46 m/s (40 m/s + 15%) would seem low in view of the expectation that tropical cyclone speeds should be above the normal. The gust speed of 50 m/s is recommended as a compromise.

For the coast represented by Group II stations, the Australian wind code gives design speeds of 69 m/s for Onslow and 63 m/s for Port Hedland. Such small distinction should not be admitted on a station by station basis and 65 m/s is recommended as the design speed for this length of coast. In this case the recommended speed is also the 50-year return period speed. For a transition zone Carnarvon to Broome, but excluding Onslow to Port Hedland, the design speed of 60 m/s is recommended, and this same speed for Willis Island.

Table 2 summarizes these recommendations and includes suggestions for design speeds for the limit state (collapse) method of design.

Conclusion

Recorded wind speeds taken during the close passing of tropical cyclones have been examined for 33 Australian stations and speed - return period relationships have been obtained. For the tropical cyclone prone parts of the Australian coast, excluding Onslow to Port Hedland, some support has been given by an independent analysis using central pressure data together with frequencies of coast crossings. Comparison with the East coast of the United States by this same inferential method suggests that in fact only Onslow to Port Hedland, the hardest hit part of the Australian coast, has similar vulnerability to the East coast of the United States as a whole. Recommended design speeds are, for most of Australia, considerably below those at present in use.

Even if these statistical approaches are accepted as valid, a drop in design speed from the order of 55 m/s to 40 m/s may not be palatable, and therefore it is perhaps timely to reconsider if the generally accepted design return period of 50 years is relevant. Should we be looking to a return period of say 200 years in order to obtain design speeds which are acceptable? At such long return periods we are very uncertain of the results, so should we abandon the concept of return period?

TABLE 2

SUMMARY OF DESIGN GUST SPEED RECOMMENDATIONS (m/s)

Coastal Section	Working stress design (nominally 50 year)	Limit state design (nominally 1000 year)
Geraldton through North to Brisbane, except as below.	50	70
Carnarvon to Broome, except as below. Also Willis Island.	60	80
Onslow to Port Hedland	65	90

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